Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

Reserve
1
Ag84Mv

LIBRARY
CUR
★ JUL 7 1950
U. S. DEPARTMENT OF AGRICULTURE

CABBAGE, CELERY, LETTUCE, AND TOMATOES

LABORATORY TESTS OF STORAGE METHODS

MARKET QUALITY RESEARCH DIVISION
AGRICULTURAL MARKETING SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

MARKETING RESEARCH REPORT NO. 402

ACKNOWLEDGMENTS

Acknowledgment is made of the cooperation and funds furnished by the Research and Development Division, Bureau of Supplies and Accounts, U. S. Department of the Navy, which made these tests possible. Acknowledgment is also made of the assistance and guidance furnished by H. T. Cook, Assistant Director, Market Quality Research Division, U. S. Department of Agriculture, under whose general direction these studies were conducted. The studies are part of a broad program of research designed to reduce marketing costs and expand markets for farm products.

CONTENTS

	Page
Summary	3
Introduction	4
Review of literature	4
Storage tests with cabbage, celery, and lettuce	5
Materials and methods	5
Results	7
Cabbage	7
Celery	10
Lettuce	15
Storage and ripening tests with tomatoes	25
Materials and methods	25
Results	25
Suggested application of findings	27
Literature cited	29

5c
June 1960

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D. C.

CABBAGE, CELERY, LETTUCE, AND TOMATOES

Laboratory Tests of Storage Methods

By C. S. Parsons, horticulturist,
L. P. McColloch, pathologist, and
R. C. Wright, horticulturist,[1]
Market Quality Research Division,
Agricultural Marketing Service

SUMMARY

Cabbage, celery, and lettuce, packaged in various ways, were stored at 32°, 38°, and 45° F. to determine the optimum method of handling each vegetable to assure its maximum storage life. Tomatoes, ripened and unripened, were stored at various temperatures to determine the best method of maintaining quality and lengthening their storage life.

Results were about the same when the vegetables were stored in sealed, unperforated plastic crate liners or individual bags, and when they were stored in unsealed, perforated liners and bags. Because of this and because produce is sometimes damaged by major changes of the atmosphere that may occur in sealed, unperforated containers, it is suggested that only perforated or unsealed liners and bags be used for storing cabbage, celery, lettuce, or similar produce.

Cabbage kept about equally well at 32° or 38° F. for periods up to 6 weeks but kept slightly better at 32° for longer periods. It deteriorated most rapidly at 45° where its condition was only fair after 4 weeks' storage.

Weight loss of cabbage stored in unlined crates increased with the length of the storage period, and ranged from 5.0 percent of the original weight after 3 or 4 weeks at 32° F. to 13.7 percent after 7 or 8 weeks at 45°. This loss, principally by evaporation of moisture, was manifested by a moderate to severe wilting of the cabbage. The use of perforated or unperforated polyethylene crate liners reduced weight loss of stored cabbage during the same periods to less than 1 percent. Cabbage losses due to discoloration, decay, and breakage were usually less in polyethylene-lined than in unlined crates. Green color in fresh cabbage was retained for longer periods in polyethylene-lined than in unlined crates.

Celery kept considerably longer at 32° F. than at 38° or 45°. When stored in unlined crates, celery wilted badly at all temperatures. When stored in polyethylene-lined crates or in individual polyethylene bags, no wilting was observed. Also, losses due to discoloration, decay, and broken leafstalks were usually less in celery packaged and stored in individual polyethylene bags than in celery stored in unlined crates.

Lettuce retained good quality for considerably longer periods at 32° F. than at 38° or 45°. It kept as well for 4 weeks at 32° as it did for only 2 weeks at 38°. Similarly, it was still as good after 6 weeks at 32° as after only 2 weeks at 45°. Weight losses up to 11 percent of the original weight occurred in lettuce stored in unlined crates. Losses in polyethylene-lined crates, in contrast, never exceeded 1 percent. Individual parchment wraps reduced weight loss in stored lettuce but not as effectively as packaging in polyethylene bags. More lettuce remained edible in polyethylene-lined than in unlined crates during storage, due principally to the reduction of weight loss. Removing wrapper leaves

[1] Mr. Wright is now retired..

from lettuce before storage proved to be the most practical method for holding the greatest amount of edible lettuce per unit of weight and space.

Mature-green tomatoes stored directly at 38° F. failed to ripen properly, became injured by low temperature, and developed extensive alternaria rot.

Mature-green tomatoes ripened slowly at 48° F. and developed less decay than tomatoes showing some color when stored for the same period of time. All of the sound fruits were edible but none ripened sufficiently at 48° to be of good quality.

Tomatoes ripened at 55° or 65° F. kept better at 32° than at 38°, but the slow ripening at 55° followed by storage at 32° and 38° favored extensive decay. Tomatoes ripened at 65° and stored at 32° and 38° kept satisfactorily for about 3 weeks.

The most successful method for extending the storage life of tomatoes was to ripen mature-green fruits at a moderate rate at 58° F., and then store them at 32° to 35°.

INTRODUCTION

Studies were initiated in 1954 at the request of the U. S. Navy to determine the best methods of handling and storing certain vegetables for maximum storage life aboard ship. Results of some of the studies were published in a previous report (10).

Vegetables often are stored longer in the Navy supply system than in domestic marketing because of the time and distance involved in transporting the produce to ships or bases abroad. Longer storage is feasible for the Navy, however, because the produce is utilized either directly from low temperature or, if transferred to another ship, is held under refrigeration until used. In domestic commerce there must always be a period for marketing, often at room temperature, following cold storage.

When supplies of fresh vegetables cannot be replenished for long periods, some loss is expected, but the important consideration is the amount that remains edible. Since space is limited on a supply ship the outer leaves or other portions that are inedible and more apt to decay could be removed before packing to increase the proportion that would remain in good edible condition. Leafy vegetables contain high percentages of water and are very susceptible to dehydration even in low-temperature storage where it is difficult to maintain high humidities. Packaging methods that decrease moisture losses during storage would be of material benefit.

REVIEW OF LITERATURE

Past studies have demonstrated the advantages of storing cabbage, celery and lettuce at temperatures near 32° F., and at high relative humidities. Platenius and others (13)[2] compared the keeping quality of many vegetables at 32°, 40°, and 50°. They found that cabbage, celery, and lettuce kept better at 32° than at the higher temperatures. Morris and others (9) concluded that temperature was usually the most important factor governing the deterioration of lettuce and that low temperatures minimized loss of quality. Stewart and Burkhart (19), in their lettuce storage studies, obtained better results at 33° than at higher temperatures. They observed that over-mature lettuce had a shorter storage life than mature lettuce but that both types kept best at low temperatures. The importance of low storage temperatures for even relatively short periods is emphasized by Stewart (18) who recommends that lettuce, which may be in storage or transit for 15 days prior to wholesaling and retailing, should be held at temperatures not exceeding 37°. The effect of only a few degrees difference in temperature on the storage life of celery was demonstrated by Thompson (20). He observed that celery in the top

[2] Underscored numbers in parentheses refer to items in the Literature Cited, p. 29.

tier of crates in the storage room, where the temperature was 35° to 36°, showed a much larger proportion of decay than that in the lower tiers where the temperature was 32°.

Some form of protection against moisture loss from green, leafy vegetables in storage is usually beneficial if the original crispness of the vegetables is to be retained. Work (21) reported that refrigerated storage at low temperature and high humidity is essential for good keeping of celery. In his studies he also found that parchment wraps aided in retarding moisture loss as reflected in reduced weight loss and deterioration in stored celery. Comin and Junnila (2) also have observed the importance of high humidities for maintaining quality of vegetables in storage. They found that, after 82 days in common storage, cabbage had lost 23 percent of its original weight at 50 percent relative humidity but had lost only 11 percent at 70 percent relative humidity. In investigating the reduction of moisture loss of vegetables stored in transparent films, Hardenburg (3) noted that the shelf life of lettuce under either nonrefrigerated or refrigerated conditions was doubled by the use of a cellophane or rubber hydrochloride (Pliofilm) overwrap. Similar benefits of film packaging were obtained by Hauck (4), and Hauck and Crawford (5), with lettuce and celery. They believed that packaging alone, through protection against physical damage and dehydration, lengthened the shelf life of the vegetables about the same as refrigeration alone. Packaging and refrigeration together produced results better than either alone. Stahl and Vaughan (17) stored cabbage, celery, and lettuce in 20- or 40-gage rubber hydrochloride film and recorded striking reductions in weight losses. Unwrapped cabbage, for example, lost 15 to 20 times more weight at 37° than that wrapped in 40-gage film. They also observed that film-wrapped vegetables retained their green coloration longer than unwrapped vegetables. Schomer and others (16) used cellophane and rubber hydrochloride film wraps in storage tests with celery but found no difference, after storage, in the color of wrapped and unwrapped stalks. They concluded that the principal effect of packaging celery in film was the reduction of moisture loss and wilting. In their tests, wrapping the celery did not reduce decay. Bratley (1) and Phillips (11) found that moisture-retentive films hastened the development of decay in lettuce and celery. They believed this disadvantage, however, was offset by the reduction in moisture loss. Rygg and McCoy (14, 15) tested various films for packaging lettuce and celery and found that perforated film packages usually gave as good or better results than unperforated packages. Off-odors were present in some unperforated packages of celery but not in perforated packages. Off-odors did not develop in either perforated or unperforated film bags of lettuce in refrigerated storage. However, after 2 days at 70° F., off-odors were detected in almost all of the film bags tested. Platenius (12) pointed out that severe wilting occurs in most fruits and vegetables if weight loss exceeds 10 percent. In tests of several films, he noted that two to twelve 1/8-inch vent holes had no appreciable effect on moisture loss from 1-pound packages of several vegetables. The vent holes prevented any fermentation due to lack of oxygen.

STORAGE TESTS WITH CABBAGE, CELERY, AND LETTUCE

Materials and Methods

Sixty-four tests were conducted from May 1954 to September 1957. Fourteen were conducted with cabbage, 11 with celery, and 39 with lettuce. All produce used in the tests was purchased at the Washington, D. C., or Baltimore, Md., wholesale markets. Cabbage was received in wirebound crates or open-mesh bags, each weighing approximately 50 pounds. Celery was received in nailed or wirebound crates, each holding 2-1/2 or 3 dozen stalks. Lettuce was received in wirebound crates or corrugated cartons, each holding 2 dozen heads. An average of 20 commercial packages was used for each cabbage test, 21 for each celery test, and 33 for each lettuce test.

The test lots originated in most of the principal vegetable growing areas of the United States. Eight lots of cabbage, grown in Northern States, represented late cabbage and six lots, from Southern States, represented early cabbage. Five lots of celery

originated in Florida, three in California, two in New Jersey, and one in New York. Five lots of lettuce originated in New Jersey, two in Texas, one in Wisconsin, and the remaining 31 in the principal production areas of Arizona and California.

The temperature of the produce varied considerably on arrival at terminal markets. Cabbage was usually trucked to market and seldom received any refrigeration. The temperature of the various lots ranged from 45° to 74° F. Celery was generally hydrocooled before shipment and the arrival temperatures ranged from 50° to 55°. Thirty-three of the 39 lots of lettuce were vacuum-cooled before shipment; 1 was ice-packed in a refrigerator car; and the remaining 5 were fan-cooled in the trucks in which they were delivered to market. The average temperature of the lettuce, on arrival, was 42°.

Only fresh-appearing produce, free of obvious disease and insect injury, and of good color, was used in the tests. No attempt was made to identify the particular strains or varieties that were used. However, the cabbage was the round-head type, celery was the Pascal type, and lettuce was generally a strain of the Great Lakes or Imperial variety.

At the Beltsville, Md., laboratory of the Market Quality Research Division the produce in each lot was randomized, and broken or bruised leaves and any decayed areas were removed. Butts were trimmed only when decay was evident. The upper inch of each stalk of celery, usually bruised or broken during transit, was always removed. After randomizing and trimming, the produce was repacked into experimental packages and stored in refrigerated rooms.

The principal types of storage packages tested are listed below. Two or more of the experimental packages were included in each test.

Cabbage:
1. Polyethylene-lined crate or box with liner unperforated (sealed).
2. Polyethylene-lined crate or box with liner perforated.
3. Unlined crate or box. (Control.)

Celery:
1. Polyethylene-lined crate with liner unperforated (sealed).
2. Polyethylene-lined crate with liner perforated.
3. Unlined crate with individual stalks in unperforated (sealed) polyethylene bags.
4. Unlined crate with individual stalks in perforated polyethylene bags.
5. Unlined crate with individual stalks in parchment wraps.
6. Unlined crate. (Control.)

Lettuce:
1. Polyethylene-lined crate or carton, with liner perforated or unsealed, trimmed heads.[3]
2. Polyethylene-lined crate or carton, with liner perforated or unsealed, untrimmed heads.
3. Unlined crate or carton with individual, trimmed heads in polyethylene bags.
4. Unlined crate or carton with individual, trimmed heads in parchment wraps.[4]
5. Unlined crate or carton, trimmed heads.
6. Unlined crate or carton, untrimmed heads. (Control.)

The polyethylene liners measured 30 x 36 inches and were formed from 2.0-mil stock. The individual, gusseted, polyethylene bags measured 8 x 4 x 19 inches and were formed from 1.5-mil stock. Parchment wraps were made of 35-pound stock and measured 18 inches square. Perforated polyethylene bags contained two or eight 1/4-inch holes, and perforated liners 2 to 48 holes. The tops of the liners and bags were usually sealed, either with heat or by tying. In some tests, however, they were merely folded over.

---

[3] Trimmed heads are heads from which 3 to 8 wrapper leaves were removed before storage.
[4] Standard method of preparing lettuce for Navy supply ships or overseas bases.

The produce in each lot was divided equally by the number of different types of storage packages used in the test. Eight or nine samples were then prepared for each type of package. Before packaging, an equal number of heads or stalks in each of the samples were weighed and the weights recorded on the butts. Three of the samples were stored at 32°, three at 38° F., and two or three at 45°. Thirty-two degrees represented the optimum storage temperature, and 38° and 45° represented storage temperatures used aboard supply ships. The relative humidity in the storage rooms was usually maintained at about 90 percent but, in two tests, humidities of 80 and 95 percent were used for comparing the effects of humidity on the storage life of lettuce.

Some of the cabbage and celery samples were inspected after 3 or 4 weeks, others after 5 or 6 weeks, the rest after 7 or 8 weeks in storage. Lettuce was inspected after 2, 4, and 6 weeks. One sample in each type of package at each temperature was used for an inspection. Each sample consisted of the number of heads or stalks usually packed in a commercial container except, in a few tests, samples one-half this size were used. Concentrations of carbon dioxide and oxygen in polyethylene liners and bags were measured prior to opening at each inspection with an Orsat-type gas analyzer and a Beckman oxygen analyzer. Stalks or heads weighed before storing were reweighed at each inspection to determine the weight loss. Color, crispness, and flavor of the produce in each test package were evaluated at each inspection. All decayed, broken, or discolored portions were then removed from the stalks or heads and the percentage remaining edible in each type of package was determined.

In addition to the principal lettuce tests in which the removal of wrapper leaves and packaging was done at Beltsville, tests were also conducted in which the wrapper leaves were removed and the lettuce packaged in California or Arizona immediately after the heads were harvested. The test packages were then shipped with commercial consignments to Washington, D. C., and stored at Beltsville.

Tests also were conducted to evaluate the effectiveness of six different films for prepackaging lettuce and celery. Both perforated and unperforated bags of each film were evaluated. The following films were used:

Cellophane (300 MSAD)	Rubber hydrochloride (Pliofilm 120 HP)
Cellophane (300 LSAD)	Polyester (Mylar, 1.0-mil)
Polyethylene (1.5-mil)	Polyvinylidene chloride (Saran, 75 DW)

Results

Cabbage

Storage temperature.--Low temperature was most important in maintaining the original quality of cabbage. Cabbage kept best at 32° F., and better at 38° than at 45° (fig. 1). The differences were most pronounced after prolonged storage.

Weight loss before trimming.--Even though stored at a relative humidity of about 90 percent, cabbage in unlined containers suffered serious weight loss at all temperatures (table 1). The loss in polyethylene-lined containers was negligible. Visible wilting occurred when the weight loss exceeded about 5 percent of the original fresh weight.

Polyethylene liners eliminated all signs of wilting in cabbage. Weight loss in polyethylene-lined containers never exceeded 1 percent of the original weight even after 7 or 8 weeks' storage. Weight losses in perforated and unperforated liners were very similar. Perforating the 30 x 36-inch liner with eight or sixteen 1/4-inch holes did not materially increase weight loss.

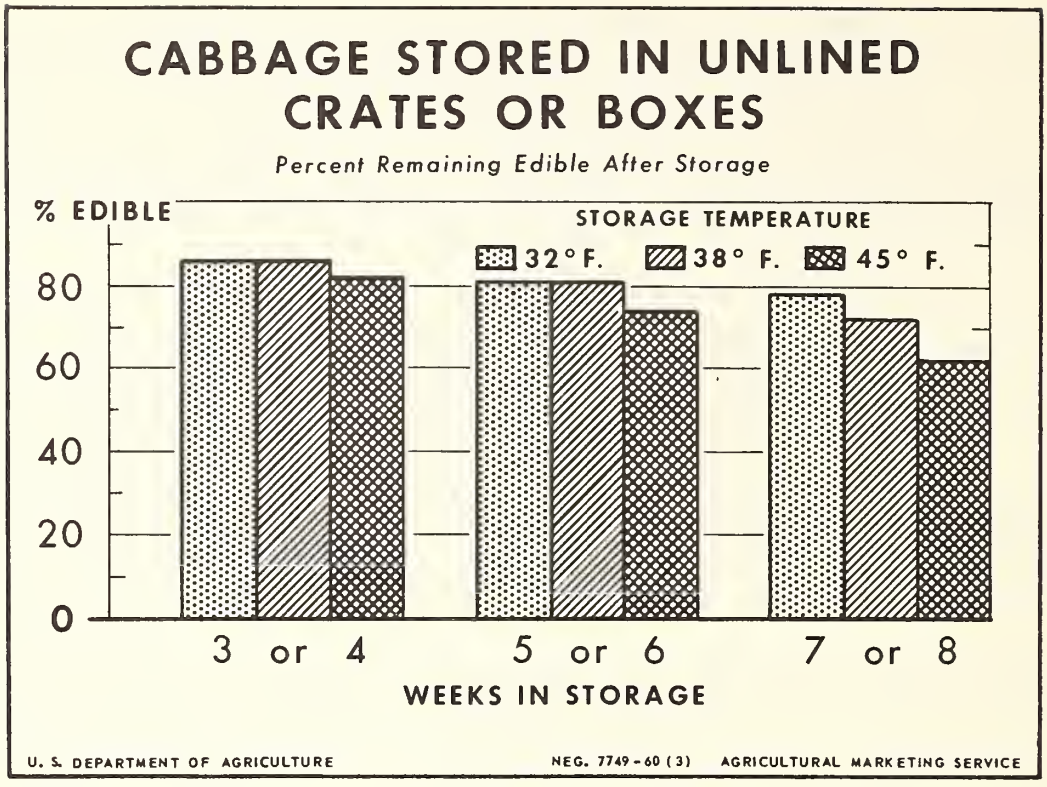


Figure 1

Table 1.--Percentage of weight loss in untrimmed cabbage after storage for various periods at 32°, 38°, and 45° F. and at a relative humidity of approximately 90 percent, in perforated and unperforated polyethylene liners and in unlined containers

Type of crate or box liner and storage temperature	Storage period		
	3 or 4 weeks	5 or 6 weeks	7 or 8 weeks
Unperforated polyethylene liner:	*Percent*	*Percent*	*Percent*
32° F.	0.3	0.1	0.4
38° F.	0.1	0.2	0.1
45° F.	0.1	0.1	0.2
Perforated polyethylene liner:[1]			
32° F.	0.2	0.2	0.5
38° F.	0.3	0.3	0.2
45° F.	0.4	0.5	0.9
Unlined crate or box (control):			
32° F.	5.0	7.0	11.7
38° F.	5.2	7.5	13.0
45° F.	6.9	10.5	13.7

[1] Each having eight 1/4-inch holes (2 tests) or sixteen 1/4-inch holes (1 test).

Trimming loss. --Comparisons were made of trimming losses (weight lost because of decayed, broken, or discolored leaves that had to be removed) of cabbage stored in perforated and unperforated polyethylene liners and in unlined containers (table 2). The smallest loss was usually found in cabbage stored in unperforated liners or in liners perforated with eight 1/4-inch holes. Increasing the number of perforations in the liners or the use of unlined containers usually resulted in a greater trimming loss.

The results of these tests indicate that some modification of the atmosphere within the liners may have aided in extending the storage life of cabbage. It should be noted that table 2 includes only the loss due to trimming. When weight loss before trimming also is considered (table 1) cabbage had smaller losses in almost all perforated and unperforated polyethylene liners than in unlined containers.

Table 2.--Percentage of trimming loss in cabbage stored for various periods at 32°, 38°, and 45° F. and at a relative humidity of 90 percent, in perforated and unperforated polyethylene liners and in unlined containers

Type of crate or box liner and storage temperature	Storage period		
	3 or 4 weeks	5 or 6 weeks	7 or 8 weeks
	Percent	*Percent*	*Percent*
Unperforated polyethylene liner:			
32° F.	4.4	3.8	11.8
38° F.	5.0	4.1	8.2
45° F.	6.6	8.1	16.8
Perforated polyethylene liner (8-hole):			
32° F.	5.4	3.2	8.1
38° F.	6.9	3.9	9.8
45° F.	5.6	14.4	13.8
Perforated polyethylene liner (16-hole):			
32° F.	8.4	8.2	13.4
38° F.	10.4	8.8	12.0
45° F.	9.8	16.7	31.6
Unlined crate or box (control):			
32° F.	5.3	8.5	13.4
38° F.	6.6	9.1	18.6
45° F.	9.2	22.7	18.1

Atmospheric changes within polyethylene liners. --The normal content of carbon dioxide and oxygen in the atmosphere (approximately 0.03 and 21.0 percent, respectively) was greatly modified within unperforated polyethylene liners, and was slightly modified in liners perforated with only two 1/4-inch holes. In liners perforated with eight or sixteen 1/4-inch holes, almost no change occurred (table 3).

Slight modification of the atmosphere through normal respiration may be beneficial, but a pronounced modification may cause undesirable odors and off-flavors. For instance, it was observed that a strong off-flavor was usually present in cabbage stored in an atmosphere containing 20 percent or more of carbon dioxide. In a few cases, off-flavors were produced in atmospheres containing less than 10 percent carbon dioxide. No off-flavor was detected in cabbage stored in perforated liners. A slight, "krauty" odor was sometimes noted immediately after the perforated liners were opened, but it dissipated quickly and had no lasting effect on the quality of the cabbage.

Table 3.--Percentage of carbon dioxide and oxygen in unperforated and perforated polyethylene crate liners containing cabbage, after storage for various periods at 32°, 38°, and 45° F.

Type of polyethylene liner and length of storage period	Storage temperature					
	32° F.		38° F.		45° F.	
	CO_2	O_2	CO_2	O_2	CO_2	O_2
Unperforated:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
3 or 4 weeks	11.1	3.0	7.8	4.6	7.7	4.3
5 or 6 weeks	7.7	3.9	5.6	8.9	6.4	4.0
7 or 8 weeks	12.2	4.9	7.0	6.7	10.8	5.6
Perforated--two 1/4-inch holes:						
3 or 4 weeks	2.0	17.3	1.9	18.4	2.3	18.0
5 or 6 weeks	2.5	17.8	1.0	19.5	3.5	17.5
7 or 8 weeks	2.8	16.4	2.7	16.3	1.8	17.8
Perforated--eight 1/4-inch holes:						
3 or 4 weeks	0.7	20.5	0.7	20.3	0.8	19.7
5 or 6 weeks	0.6	20.2	0.1	20.5	0.8	20.2
7 or 8 weeks	0.5	20.3	0.6	20.2	1.0	18.8
Perforated--sixteen 1/4-inch holes:						
3 or 4 weeks	0.2	19.6	0.2	19.2	0.8	18.4
5 or 6 weeks	0.1	21.0	0.2	20.8	0.6	20.8
7 or 8 weeks	0.1	21.0	0.6	21.0	1.2	20.1

Color.--Cabbage retained its fresh, green color longest when stored at low temperatures and in crates with polyethylene liners. The color was retained longer in unperforated than in perforated liners. Cabbage at 32° F. remained fresh and green in appearance for 4 weeks in both lined and unlined crates. Thereafter, only the cabbage stored in unperforated liners and in liners perforated with eight or fewer 1/4-inch holes remained green. Cabbage in unlined crates or in liners with 16 holes became yellow. The green color disappeared more rapidly from cabbage stored at 38° and 45° than from that stored at 32°, regardless of the type of container.

Celery

Storage temperature.--Celery kept best at 32° F., and better at 38° than at 45°. These differences were most pronounced after storage for 5 or 6 weeks (fig. 2). Celery in unlined crates kept only slightly better at 32° than at 38° for 3 or 4 weeks. Only 50 percent of the celery stored at 45° remained edible after 5 or 6 weeks and further storage appeared useless.

Weight loss before trimming.--Severe weight loss occurred in celery in unlined crates after only 3 or 4 weeks' storage. The loss in polyethylene bags or liners was almost negligible for the entire test period (table 4). Because of weight loss, due principally to evaporation of moisture, celery wilted in unlined crates, but remained crisp in polyethylene crate liners and bags (fig. 3).

There was no material difference between the weight losses of celery in unperforated (sealed) and perforated (unsealed) polyethylene containers.

Table 4.--Percentage of weight loss in celery stored for various periods at 32°, 38°, and 45° F. and at a relative humidity of 90 percent in various types of packages

Type of storage package and storage temperature	Storage period		
	3 or 4 weeks	5 or 6 weeks	7 or 8 weeks
	Percent	*Percent*	*Percent*
Unperforated (sealed) polyethylene crate liner:			
32° F.	0.0	0.0	0.1
38° F.	0.0	0.0	0.6
45° F.	0.0	0.0	---
Unperforated (unsealed) polyethylene crate liner:			
32° F.	0.0	1.2	1.1
38° F.	0.2	0.0	0.5
45° F.	0.0	0.5	---
Unperforated (sealed) individual polyethylene bag:			
32° F.	0.2	0.0	0.5
38° F.	0.3	0.1	1.0
45° F.	0.4	0.4	---
Perforated (sealed) individual polyethylene bag:[1]			
32° F.	0.2	0.3	0.5
38° F.	0.2	0.2	0.9
45° F.	0.4	0.8	---
Unlined crate, stalks unwrapped and unbagged (control):			
32° F.	8.2	11.1	18.5
38° F.	8.9	10.0	18.2
45° F.	11.2	13.7	---

[1] Each having two or eight 1/4-inch holes.

Weight loss was usually greater at 45° F. than at the lower temperatures, particularly of celery in unlined crates.

Celery is often sprinkled while in storage to maintain crispness. To test the effectiveness of this method, weight losses of sprinkled and unsprinkled celery in unlined crates were compared in one test with the losses of celery in polyethylene-lined crates. Each crate of sprinkled celery received 1 quart of water twice a week. This reduced weight loss considerably below that in unsprinkled celery but was far less effective than packaging the celery in polyethylene liners. For example, after 5 weeks at 32° F., unsprinkled celery had lost 7.8 percent of its original weight, sprinkled celery had lost 3.5 percent, while celery stored in polyethylene-lined crates had lost less than 1 percent.

Trimming loss.--Losses due to discoloration, decay, and breakage were usually less in celery in individual polyethylene bags than in unbagged celery (table 5). The difference occurred because the bags prevented spread of decay and reduced breakage during packing and unpacking. Trimming loss of celery stored in bags was approximately the same after 8 weeks at 32°, 6 weeks at 38°, and 4 weeks at 45°.

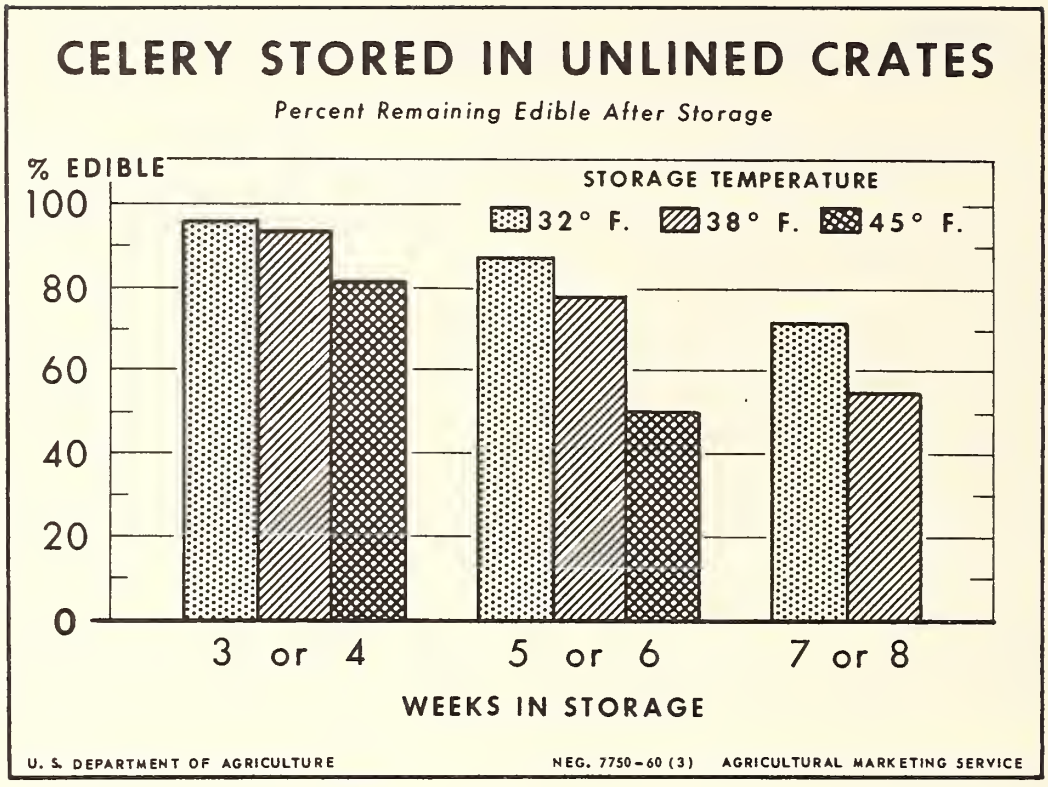
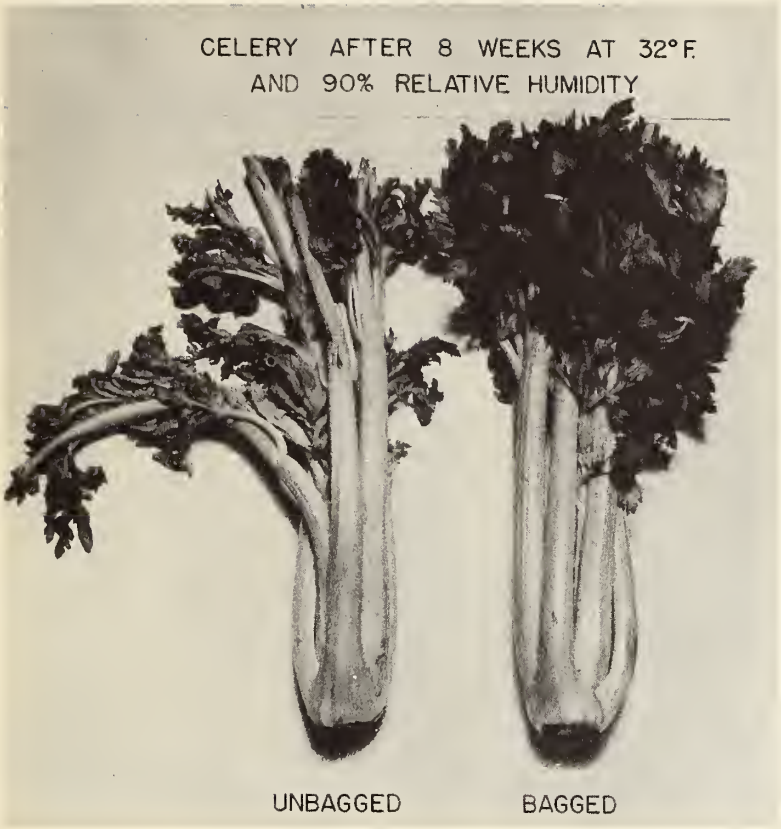


Figure 2

Trimming loss was about equal in celery stored in unperforated and perforated polyethylene bags, except after 5 or 6 weeks at 45° F. when the loss in perforated bags was about one-fourth greater than in unperforated bags.

Trimming losses of celery stored in polyethylene-lined and unlined crates were also compared in one test (table 6). Unsealed, unperforated liners were used. Losses were generally only slightly less in polyethylene-lined crates than in unlined crates. After 7 or 8 weeks at 32° F., however, celery in unlined crates was severely dehydrated, necessitating an abnormal amount of trimming. Losses in these crates were more than 3 times as great as in polyethylene-lined crates. Although trimming losses were generally reduced only slightly by packaging celery in polyethylene-lined rather than in unlined crates, weight losses were almost eliminated. Total losses of celery (trimming losses plus weight losses) were considerably less in polyethylene-lined than in unlined crates.

Parchment wraps vs. polyethylene bags.--The effectiveness of parchment wraps and polyethylene bags in retaining quality of stored celery was compared in two tests. The methods used in wrapping and bagging the celery are shown in figure 4. Each bag was perforated with two 1/4-inch holes. More of the wrapped and bagged celery was edible after storage than of the unwrapped and unbagged celery (fig. 5). Trimming losses in the packaged and unpackaged celery did not differ greatly. Weight losses, however, ranged from less than 1 percent in polyethylene bags and 4.7 percent in parchment wraps, to over 17 percent in unbagged and unwrapped stalks. This difference in weight loss was reflected in the amount of edible celery remaining after storage. Although parchment wraps reduced weight loss, they did not eliminate it and wilting was usually apparent in the wrapped celery. Weight loss in polyethylene bags was so small that no wilting occurred. Unbagged and unwrapped celery wilted severely even though stored at a relative humidity of 90 percent.



BN-9097

Figure 3.--Effect of polyethylene bags on wilting of celery.

Atmospheric changes within polyethylene packages.--The percentages of carbon dioxide and oxygen in the atmosphere changed markedly in sealed or unperforated polyethylene packages during storage but only slightly in packages which were unsealed or perforated (table 7). The major changes occurred during the first 4 weeks in storage with only minor changes thereafter. Higher percentages of carbon dioxide were found in sealed (unperforated) liners (2.0-mil) than in sealed (unperforated) bags (1.5-mil), probably due to the difference in thickness of the polyethylene stock, and to the larger surface of the bags per unit weight of celery.

In unsealed or perforated packages the highest carbon dioxide percentage found was 2.4, and in many instances it was less than 1.0. The oxygen content in the packages was reduced only slightly and averaged about 20 percent.

Changes in the carbon dioxide and oxygen content usually were greater at higher storage temperatures due to the higher respiration rate of the stored celery.

Quality evaluation.--Celery stored without wrapping or bagging, and that wrapped in parchment, was often wilted when removed from storage. The wilted leafstalks were usually tough. On the other hand, celery which was stored in polyethylene bags or liners was not wilted and always retained its crispness and tenderness.

The original green color of Pascal celery was retained for the longest period in sealed or unperforated polyethylene packages, and longer in unsealed or perforated packages than unbagged or in unlined crates.

No difference was discernible, immediately after removal from storage, in the flavor of celery stored in the various polyethylene packages and in unlined crates. Holding celery in sealed packages at room temperature for prolonged periods might result in off-flavors.

Keeping quality in various film bags.--Consumer-size film bags, made of polyester and polyvinylidene chloride of the thickness used in the test, were unsuited for storing celery for prolonged periods unless adequate ventilation was provided in the bags. Percentages of carbon dioxide and oxygen were modified so greatly in unperforated, sealed bags made of these films that undesirable odors and flavors often resulted. Carbon dioxide percentages as great as 13.0 in polyester bags and 24.0 in polyvinylidene chloride bags were found after 5 weeks in storage. Oxygen percentages as low as 6.0 were obtained in both bags during the same period.

Table 5.--Percentage of trimming loss in polyethylene-bagged and unbagged celery stored for various periods at 32°, 38°, and 45° F. and at a relative humidity of 90 percent

Type of package and storage temperature	Storage period		
	3 or 4 weeks	5 or 6 weeks	7 or 8 weeks
	Percent	*Percent*	*Percent*
Unperforated polyethylene bag:			
32° F.	1.5	3.7	11.7
38° F.	2.4	12.8	22.9
45° F.	13.5	31.0	---
Perforated polyethylene bag:[1]			
32° F.	0.9	4.8	12.2
38° F.	3.1	11.1	23.3
45° F.	14.6	40.0	---
Unlined crate, naked stalks (control):			
32° F.	3.0	6.4	20.0
38° F.	3.9	16.2	27.4
45° F.	12.2	41.3	---

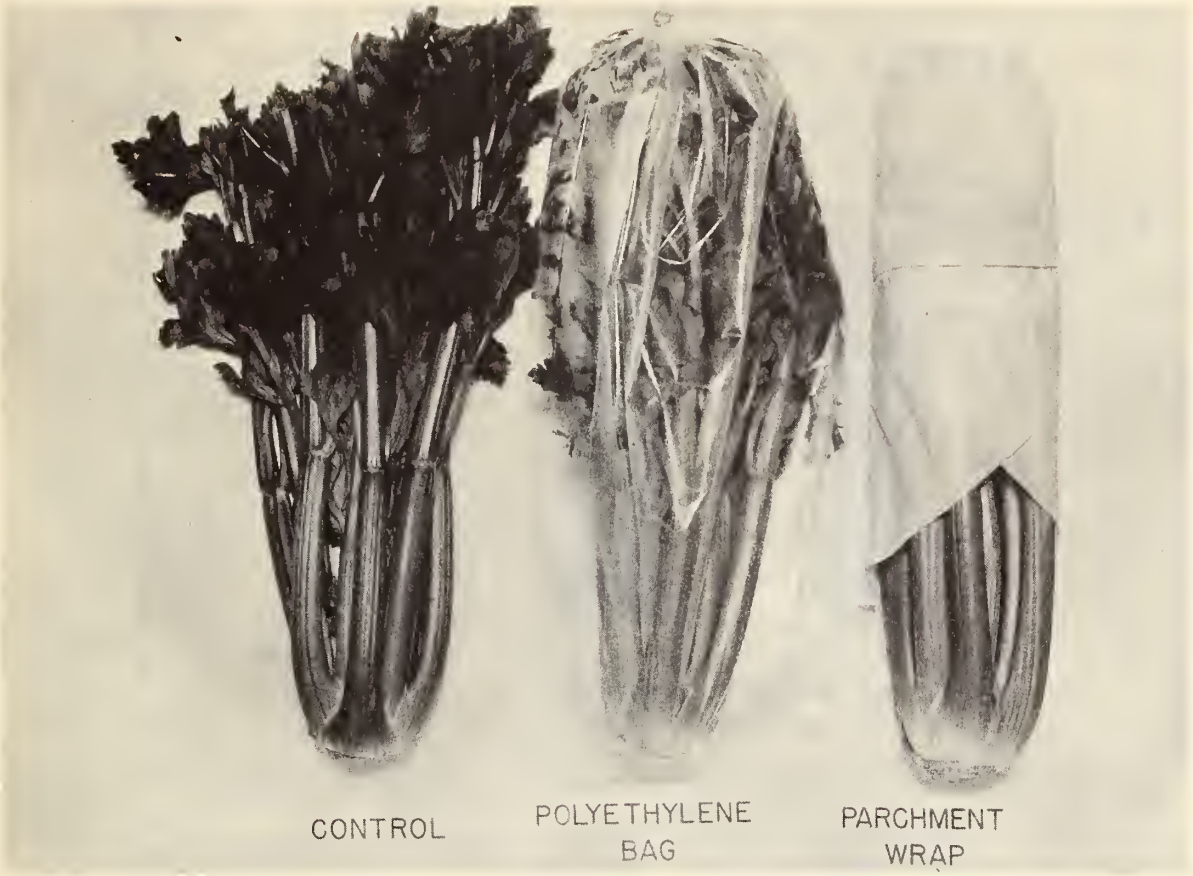
[1] Each having two 1/4-inch holes.

Table 6.--Percentage of trimming loss in celery stored for various periods at 32°, 38°, and 45° F. and at a relative humidity of 90 percent, in polyethylene-lined and unlined crates

Type of package and storage temperature	Storage period		
	3 or 4 weeks	5 or 6 weeks	7 or 8 weeks
	Percent	*Percent*	*Percent*
Polyethylene-lined crate:[1]			
32° F.	0.6	3.4	11.5
38° F.	1.4	6.5	28.4
45° F.	7.6	36.9	---
Unlined crate (control):			
32° F.	0.7	7.6	40.4
38° F.	1.6	12.3	22.5
45° F.	8.0	38.5	---

[1] Unsealed, unperforated liner.

Weight loss was far greater in semimoistureproof and moistureproof cellophane than in bags made of the other films tested. After 6 weeks at 32° F., for example, weight loss in cellophane bags ranged from 2.3 to 3.8 percent of the original weight of the celery. Losses in other film bags (polyethylene, rubber hydrochloride, polyester, and polyvinylidene chloride) did not exceed 0.4 percent. Because of this weight loss, celery stored for prolonged periods in cellophane bags, either perforated or unperforated, was often flabby when removed from storage.



BN-9098

Figure 4.--Three methods of storing celery, showing stalks at the start of the test.

Celery kept better in rubber hydrochloride and polyethylene bags than in the other types. Permeability to carbon dioxide was apparently sufficient in these films to prevent any damaging accumulation during storage, even when the bags were unperforated. The oxygen content never dropped below 9.0 percent. Moisture-retentiveness of these films was also excellent and the celery remained crisp during the entire test.

Lettuce

Storage temperature.--Lettuce kept best at 32° F., and better at 38° than at 45°. The difference in keeping quality at these temperatures was most pronounced after extended storage periods. In unlined (commercially packed) cartons or crates, 65 percent of the stored lettuce remained edible after 2 weeks at 32° as compared to 60 percent at 38°, and only 51 percent at 45° (fig. 6). Decay was slight and the inedible portions consisted mainly of broken and discolored wrapper leaves, some of which were present when the lettuce was stored. At 32° almost one-half of the stored lettuce was still edible after 6 weeks.

It was apparent that a difference of only a few degrees in storage temperature had a profound effect on keeping quality. Lettuce kept as well for 4 weeks at 32° as it did for only 2 weeks at 38°. Similarly, it was still almost as good after 6 weeks at 32° as after only 2 weeks at 45°.

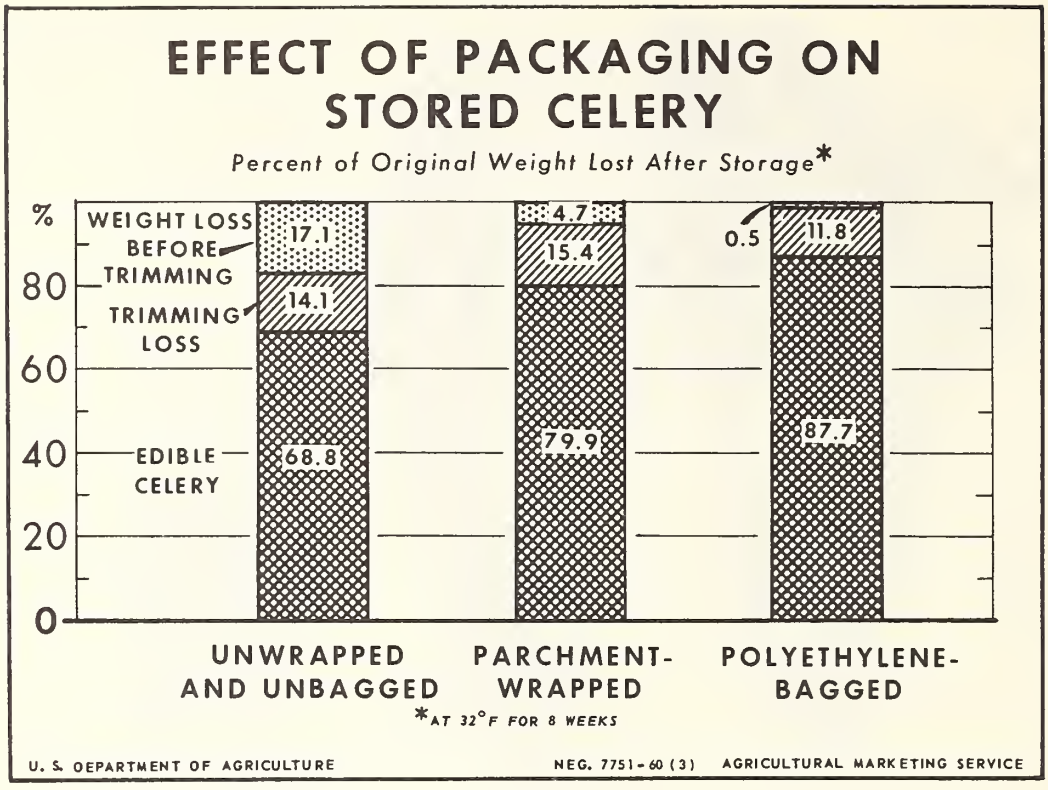


Figure 5

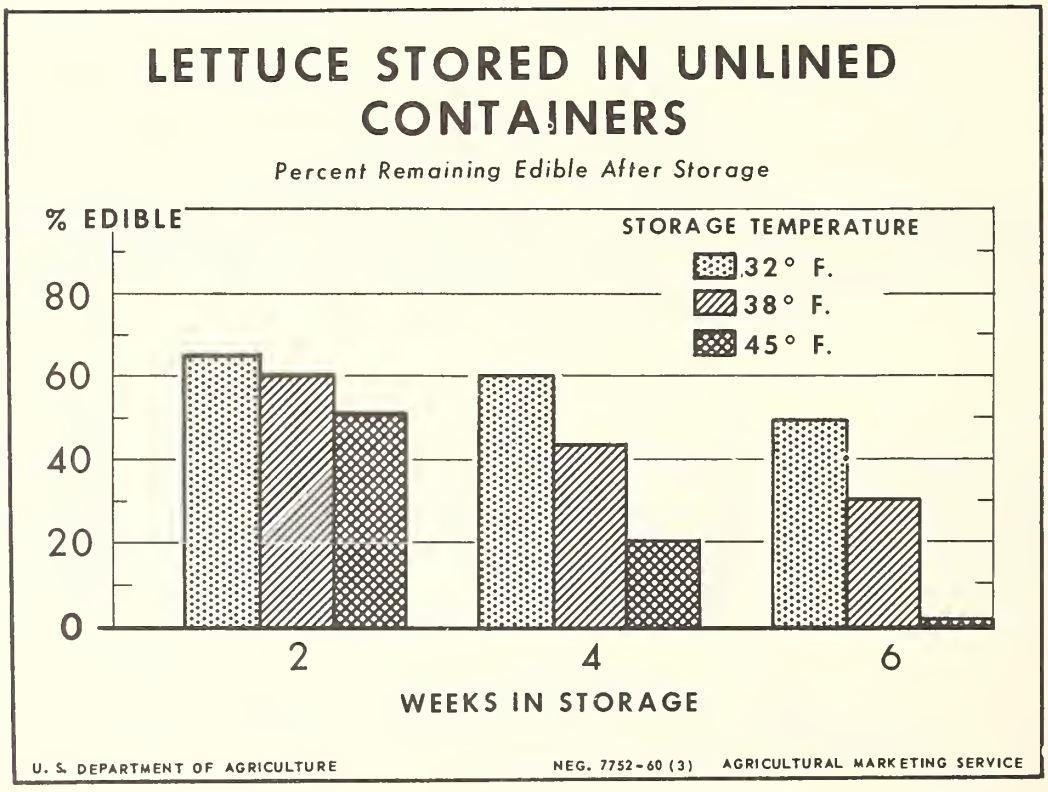


Figure 6

Table 7.--Percentage of carbon dioxide and oxygen in various packages of celery stored at 32°, 38°, and 45° F.

Type of package and storage period	Storage temperature					
	32° F.		38° F.		45° F.	
	CO_2	O_2	CO_2	O_2	CO_2	O_2
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Unperforated (sealed) polyethylene bag:						
3 or 4 weeks	2.8	11.7	2.9	9.9	3.8	5.1
5 or 6 weeks	2.4	12.2	2.7	11.2	4.5	5.1
7 or 8 weeks	2.6	12.3	3.6	9.6	---	---
Perforated (sealed) polyethylene bag:[1]						
3 or 4 weeks	1.0	19.9	1.1	19.8	1.7	18.9
5 or 6 weeks	([2])	20.2	1.5	19.3	2.4	18.4
7 or 8 weeks	([2])	19.8	([2])	20.2	---	---
Unperforated (sealed) polyethylene crate liner:						
3 or 4 weeks	5.0	11.2	5.0	10.0	8.8	11.0
5 or 6 weeks	3.9	11.4	5.2	10.8	6.0	11.5
7 or 8 weeks	4.0	13.3	6.8	9.8	---	---
Unperforated (unsealed) polyethylene crate liner:[3]						
3 or 4 weeks	([2])	20.8	([2])	21.0	([2])	21.0
5 or 6 weeks	([2])	20.9	([2])	20.8	([2])	20.6
7 or 8 weeks	2.0	19.0	2.4	19.2	---	---

[1] Containing two 1/4-inch holes each.
[2] Less than 1 percent.
[3] With top folded over only.

Relative humidity.--In two tests, lettuce in commercial (unlined) cartons was stored at 38° F. and at relative humidities of 80 and 95 percent (fig. 7). More lettuce remained edible at 95 percent relative humidity than at 80 percent relative humidity.

Fresh lettuce is composed of about 95 percent water. It loses this moisture rapidly unless stored in exceedingly humid atmospheres. Wilting was severe in lettuce stored at 80 percent relative humidity, but it was considerably less at 95 percent relative humidity.

Weight loss before trimming.--At a relative humidity of approximately 90 percent, weight loss in commercially packed lettuce (in unlined cartons) was less at 32° F. than at 38° or 45°. The loss at all temperatures increased with the storage period (table 8).

A comparison of weight loss of lettuce in unlined and polyethylene-lined cartons at 38° F. is given in figure 8. Sealed, unperforated liners were used. The weight loss in lined cartons never exceeded 0.6 percent of the original weight but the loss in unlined cartons was 5.6 percent after 2 weeks and over 11 percent after 6 weeks. Previous tests have shown that loss of about 2 percent of the original weight produces slight wilting in lettuce, and loss of 5 percent produces severe wilting.

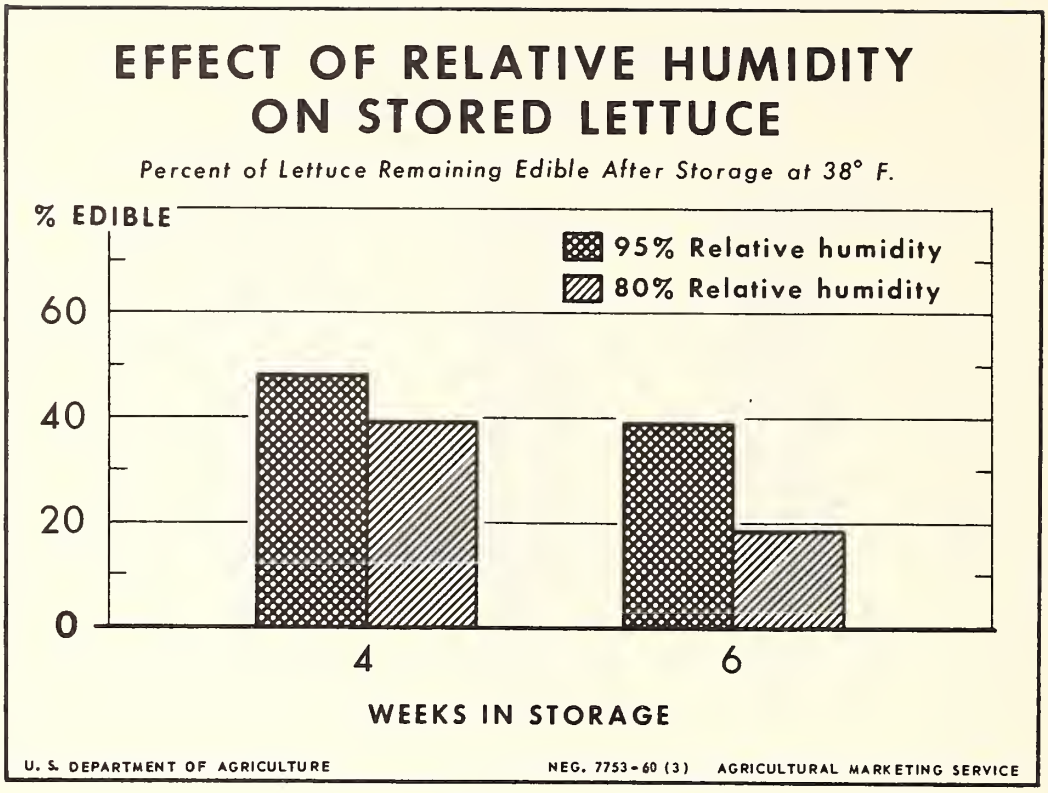


Figure 7

In further tests, weight loss of lettuce stored in unlined cartons at 32° and 45° F. was compared with that of lettuce in individual parchment wraps and in perforated (two 1/4-inch holes) polyethylene bags. Weight loss was greatest in the unlined cartons and least in the polyethylene bags. Loss in all of the storage packages was greater at 45° than at 32° (fig. 9).

Severe wilting was often noted in lettuce in unlined cartons at both 32° and 45° F., particularly after longer storage periods. Lettuce stored in parchment wraps for 4 weeks appeared slightly wilted at 32° and severely wilted at 45°. No wilting was observed in lettuce stored in individual polyethylene bags.

Table 8.--Percentage of weight loss in lettuce stored in unlined cartons after 2, 4, and 6 weeks at 32°, 38°, and 45° F. and at a relative humidity of 90 percent

Storage temperature	Storage period		
	2 weeks	4 weeks	6 weeks
	Percent	*Percent*	*Percent*
32° F.	4.4	4.6	9.6
38° F.	5.6	8.4	11.2
45° F.	4.6	8.8	---

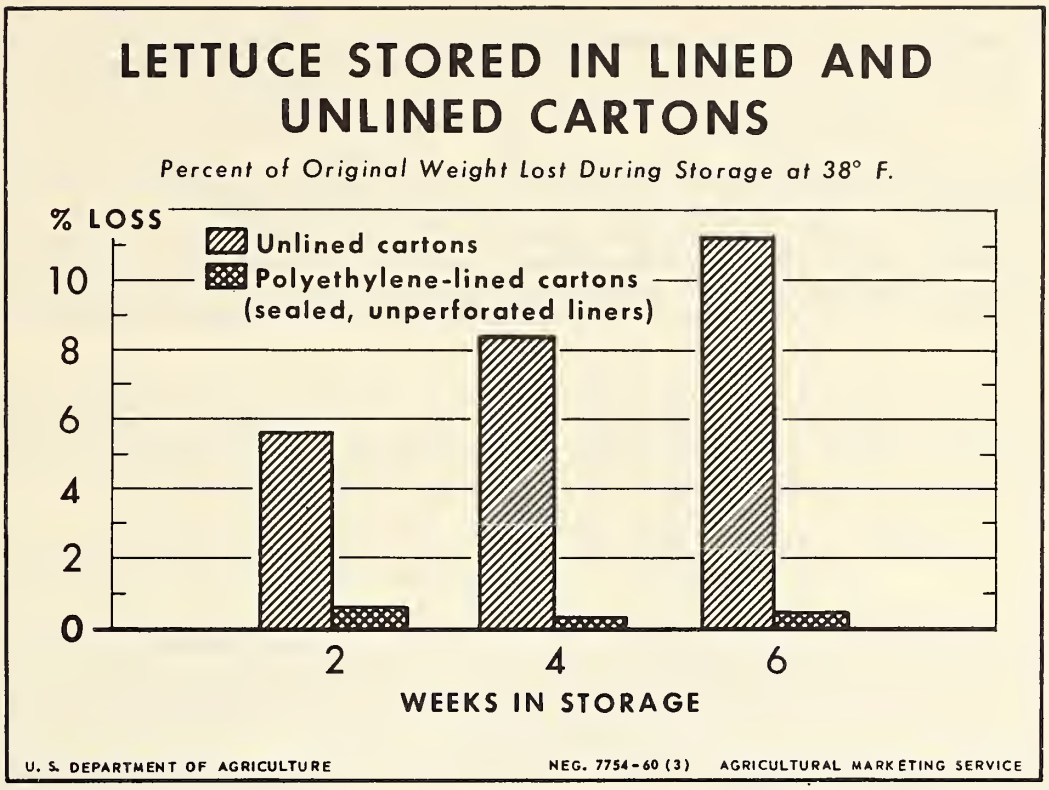


Figure 8

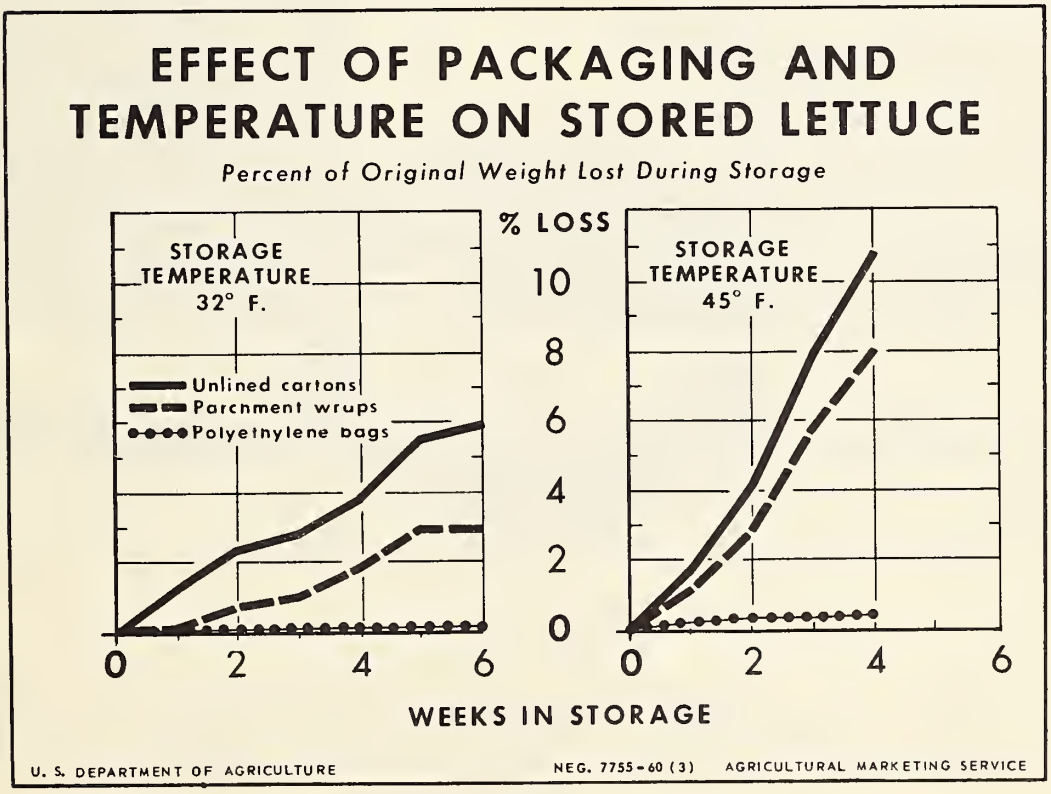


Figure 9

The results of these tests indicate that lettuce held in storage in unlined cartons for extended periods was subject to considerable drying even at a high relative humidity of 90 percent. Wrapping the heads in parchment reduced the weight loss to some extent but often not enough to prevent wilting. Storing the lettuce in individual perforated polyethylene bags practically eliminated weight loss and kept the lettuce fresh and crisp.

Keeping quality in polyethylene-lined and unlined cartons.--Nine tests were conducted to compare the keeping quality of lettuce at 32°, 38°, and 45° F. in polyethylene-lined and unlined cartons. Unperforated liners, with tops overlapped but unsealed, were used in five tests while perforated liners were used in four tests. The tops of the perforated liners were tied and each liner contained twenty-four or forty-eight 1/4-inch holes. Three to eight wrapper leaves were removed from all heads of lettuce before packaging and storing.

Lettuce kept better in polyethylene-lined than in unlined cartons. The use of liners, in most instances, increased the storage life of the lettuce almost 2 weeks over that in unlined cartons. At 32° F., for example, lettuce kept as well in polyethylene-lined cartons for 4 weeks as it kept in unlined cartons for only 2 weeks (table 9).

Table 9.--Percentage of lettuce remaining edible after storage in polyethylene-lined and unlined cartons for various periods at 32°, 38°, and 45° F

Type of carton and storage temperature	Storage period		
	2 weeks	4 weeks	6 weeks
	Percent	*Percent*	*Percent*
Polyethylene-lined (32° F.)	95	89	81
Unlined (32° F.)	88	82	74
Polyethylene-lined (38° F.)	92	78	66
Unlined (38° F.)	82	69	50
Polyethylene-lined (45° F.)	89	66	--
Unlined (45° F.)	73	45	--

The percentages given in table 9 are based on amounts of lettuce classified as edible. There was, however, a considerable difference in the quality of the edible lettuce in polyethylene-lined and unlined cartons. The edible lettuce that remained in unlined cartons was often slightly wilted and lusterless but the lettuce from polyethylene-lined cartons was crisp and fresh-appearing even after 6 weeks' storage.

Polyethylene carton liners vs. individual polyethylene bags.--Four tests were conducted to compare the keeping quality of lettuce in polyethylene carton liners and in individual polyethylene bags. Liners and bags were sealed in two tests and unsealed in the other two. No consistent difference was noted in the quality or amount of lettuce remaining edible in the two types of package (table 10).

Keeping quality of heads, trimmed or untrimmed before storage.--Wrapper leaves of lettuce, often dirty and discolored at the time of harvest, are usually bruised or broken during packing and shipment. In this condition, they are highly susceptible to decay. They are always removed from the heads after the lettuce has reached its destination and before it is consumed. Therefore, these wrapper leaves might well be considered inedible waste. They are left intact solely to provide some protection against bruising and breaking of the solid portion of the head during packing and shipment. The weight and bulk of wrapper leaves are considerable, as shown in figure 10. In this particular lot, the heads of lettuce with wrapper leaves removed weighed 28 percent less

Table 10.--Percentage of lettuce remaining edible in polyethylene carton liners and in individual polyethylene bags after various periods at 32° and 38° F.

Type of polyethylene container and storage temperature	Storage period		
	2 weeks	4 weeks	6 weeks
	Percent	*Percent*	*Percent*
Carton liner (32° F.)	90	82	69
Individual bag (32° F.)	90	81	70
Carton liner (38° F.)	88	76	53
Individual bag (38° F.)	86	68	53

than the untrimmed heads and occupied considerably less space. These reductions in weight and bulk are especially significant when one realizes that the weight of edible lettuce, with or without wrapper leaves, is essentially the same.

BN-9099

Figure 10.--Lettuce before and after removing wrapper leaves showing amount of trim removed. Note reduced volume occupied by trimmed heads.

Seven tests were conducted to compare the keeping quality of lettuce stored with and without wrapper leaves (trimmed). Three to eight wrapper leaves were removed from each of the trimmed heads, reducing the weight of the heads by 25 to 30 percent. The weight of each carton of heads with wrapper leaves removed averaged 28 pounds when

placed in storage as compared to 39 pounds for each carton of heads with wrapper leaves attached. Removing the wrapper leaves reduced the volume occupied by 24 heads from approximately 2 cubic feet to slightly more than 1-1/2 cubic feet.

Figure 11 shows the percentages of lettuce remaining edible after 4 weeks at 32°, 38°, and 45° F. when stored with or without wrapper leaves. These percentages are based on initial stored weight of the lettuce. The greatest proportion of stored lettuce remained edible in cartons containing heads that were trimmed before storage. This was due to the fact that, in removing the wrapper leaves before storage, a considerable percentage of the inedible portion of untrimmed heads was eliminated. When based on actual weights of edible lettuce, about equal amounts were observed in lettuce stored with or without wrapper leaves.

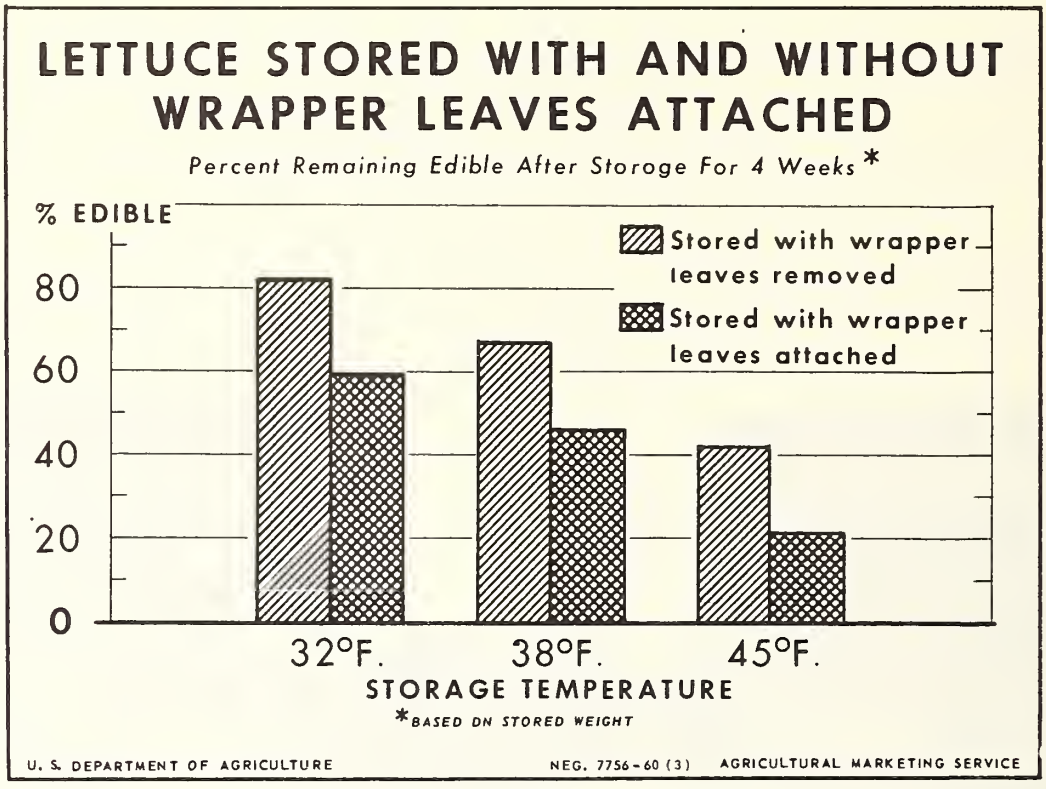


Figure 11

Attached wrapper leaves provide considerable protection against drying of the solid portion of the lettuce head. When the wrapper leaves are removed, the remaining head is more susceptible to drying, particularly when it is stored for extended periods at low relative humidities. For this reason, some protection should be provided to prevent drying when storing heads of lettuce without the wrapper leaves. Polyethylene carton liners or individual bags proved very effective for this purpose.

Keeping quality in various types of film bags.--Lettuce in each of six types of film bags kept better than unbagged lettuce because of reductions in trimming and weight losses. Perforated bags made of the less permeable films (polyester and polyvinylidene chloride) gave better results than unperforated bags made of these films. Conversely, unperforated bags gave the best results when more permeable films, such as cellophane, polyethylene, and rubber hydrochloride, were used.

Lettuce remained in excellent condition for 6 weeks in unperforated bags of rubber hydrochloride and polyethylene, and in perforated bags of polyester, but deteriorated more rapidly in perforated and unperforated bags made of the other films (table 11).

Table 11.--Trimming and weight losses of lettuce stored in perforated and unperforated bags of various films after 2, 4, and 6 weeks at 32° F. and a relative humidity of approximately 90 percent

Type of bag and length of storage period	Unperforated bags			Perforated bags		
	Trimming loss	Weight loss	Total loss	Trimming loss	Weight loss	Total loss
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Polyester (Mylar):						
2 weeks	0.0	0.2	0.2	0.0	0.2	0.2
4 weeks	0.6	0.3	0.9	0.6	0.2	0.8
6 weeks	7.9	0.4	8.3	2.0	0.3	2.3
Cellophane (MSAD):						
2 weeks	0.6	0.2	0.8	1.8	0.2	2.0
4 weeks	4.0	0.4	4.4	4.0	0.5	4.5
6 weeks	8.6	0.6	9.2	8.6	0.7	9.3
Cellophane (LSAD):						
2 weeks	1.9	0.4	2.3	5.8	0.4	6.2
4 weeks	3.4	1.0	4.4	4.6	1.0	5.6
6 weeks	6.6	1.6	8.2	11.7	1.2	12.9
Rubber hydrochloride (Pliofilm):						
2 weeks	0.0	0.1	0.1	0.0	0.1	0.1
4 weeks	0.2	0.2	0.4	1.6	0.3	1.9
6 weeks	2.6	0.3	2.9	9.8	0.3	10.1
Polyvinylidene chloride (Saran):						
2 weeks	0.0	0.1	0.1	0.0	0.1	0.1
4 weeks	1.4	0.1	1.5	1.3	0.1	1.4
6 weeks	12.0	0.2	12.2	6.8	0.2	7.0
Polyethylene:						
2 weeks	0.0	0.1	0.1	0.0	0.1	0.1
4 weeks	0.0	0.1	0.1	4.2	0.1	4.3
6 weeks	2.0	0.2	2.2	5.9	0.2	6.1
None (control):						
2 weeks	4.8	3.3	8.1	4.8	3.3	8.1
4 weeks	6.6	5.8	12.4	6.6	5.8	12.4
6 weeks	14.3	9.0	23.3	14.3	9.0	23.3

Weight loss (principally of moisture) was far greater in unbagged lettuce than in bagged lettuce, and slightly greater in semimoistureproof cellophane bags than in bags made of the other films. No marked difference was noted between weight losses of lettuce in perforated and unperforated bags of any of the films tested.

The normal atmosphere of carbon dioxide and oxygen was so greatly modified in unperforated bags of polyester and polyvinylidene chloride (17.0% CO_2 and 9.7% O_2) that lettuce in these bags was sometimes damaged. Perforated bags of these films, however, proved satisfactory for storing lettuce. Lettuce in unperforated bags of the more permeable films (cellophane, rubber hydrochloride, and polyethylene) was not affected by

the slight modification of the atmosphere that occurred. Lettuce used in these tests was stored at 32° F. where the respiratory rate was greatly retarded. Holding the bagged lettuce at higher temperatures would undoubtedly produce a greater modification of the atmosphere within all bags which, in turn, might damage the lettuce. Perforating the bags would probably eliminate the danger, regardless of the storage temperature.

Removal of wrapper leaves before or after transit.--Lettuce in unlined cartons kept about equally well when wrapper leaves were removed either immediately after harvest or after an 8-day transit period (table 12). In addition, the removal had no material effect on the amount of bruising that occurred during transit. However, the wrapper leaves added considerably to the shipping weight.

Table 12.--Percentage of trimmed lettuce remaining edible after storage in unlined cartons for various periods at 32° F.

Time of trimming[1]	Storage period		
	2 or 3 weeks	4 or 5 weeks	6 or 7 weeks
	Percent	*Percent*	*Percent*
Immediately after harvest.....	73	65	54
After 8 days in transit to market.....	74	66	60

[1] 3 to 8 wrapper leaves were removed.

When wrapper leaves were removed immediately after harvest, considerably greater amounts of lettuce remained edible at the various inspections when it was shipped and stored in polyethylene-lined cartons (unsealed liners) rather than in unlined cartons (fig. 12). The differences were due largely to prevention of moisture loss from lettuce in the lined cartons.

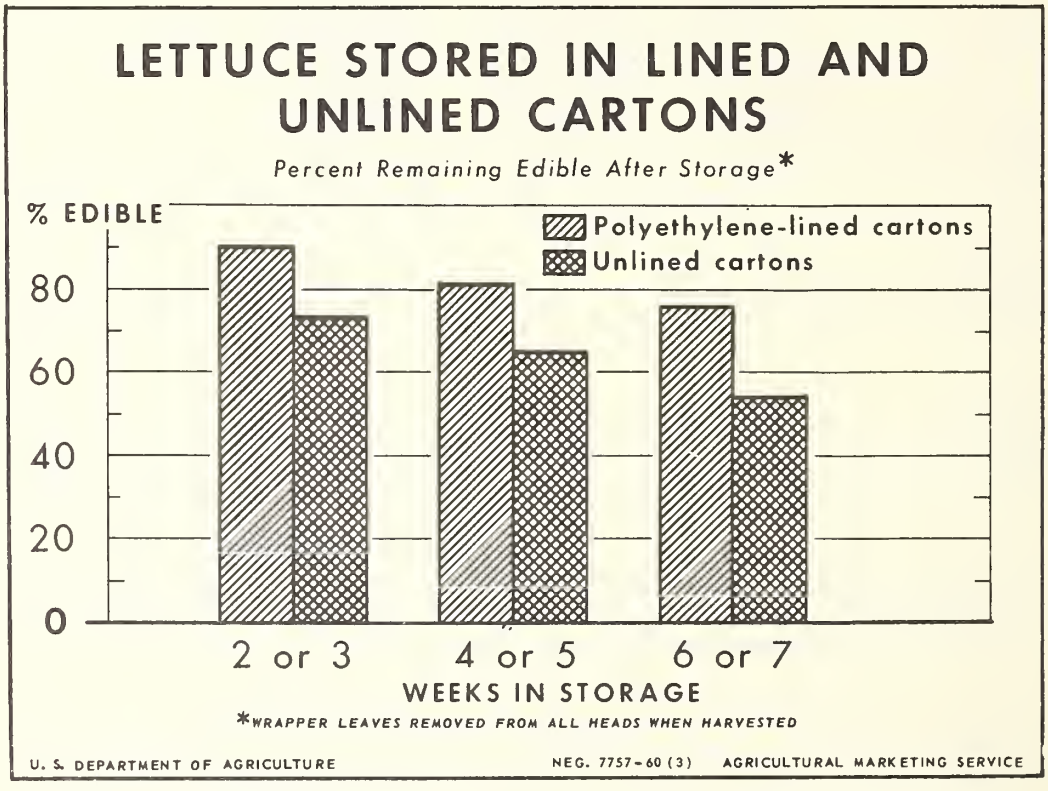


Figure 12

STORAGE AND RIPENING TESTS WITH TOMATOES

Materials and Methods

Tests were conducted during three seasons to determine methods for successfully handling tomatoes in the Navy supply system. Florida-grown tomatoes, harvested mature green and commercially packed, were used.

Four general methods of handling were tested under laboratory conditions with controlled temperature facilities: (1) Mature-green tomatoes were stored at 38° F. for 21 days and then placed under favorable ripening conditions at 65°; (2) mature-green tomatoes and others at various stages of color development were ripened slowly at a continuous storage temperature of 48°; (3) mature-green tomatoes were ripened at a moderately slow rate at 55° until firm ripe and then stored at 32° and 38°; (4) mature-green tomatoes were ripened at a normal rate at 65° until firm ripe and then stored at 32° and 38°.

Results

Mature-green tomatoes held at 38° F. for 21 days and then at 65° for 5 days developed alternaria rot (fig. 13). None were edible. Numerous tests have shown that mature-green tomatoes cannot be ripened satisfactorily after prolonged holding at low (32° to 45°) temperature (6, 7, 8). At low temperature tomatoes become weakened and extensive decay develops when they are placed at temperatures favorable to ripening.

BN-9100

Figure 13. --Mature-green tomatoes stored at 38° F. for 21 days, then held at 65° for 5 days. All the fruits in test developed alternaria rot as shown.

In an effort to extend the storage life of fresh tomatoes for Navy supply ships they were ripened slowly at 48° F. A series of fruits from mature green through various stages of color development, including 85 percent colored, was included. The results are shown in table 13.

The condition of tomatoes held at 48° F. for 24 days depended on the stage of ripeness when stored. Tomatoes stored mature green and ripened slowly at 48° developed the least decay. They were edible but not ripe enough for good quality. Tomatoes with

Table 13.--Condition of tomatoes after 24 days if stored mature green, turning, and ripe at 48° F.

Extent of color when stored	Total fruits	Condition at end of storage		
		Extent of color	Edible	Decayed
	Number	*Percent*	*Percent*	*Percent*
0 (mature green)	126	60-85	91	9
0-20 percent	68	75-88	85	15
20-40 percent	100	75-85	73	27
50 percent	102	75-86	73	27
75 percent	119	80-88	65	35
85 percent	182	85-88	23	77

more than 20 percent color when stored at 48° developed slightly more color but also more decay than those stored mature green. Decay during storage generally increased with the degree of ripeness at the time of storage.

Tomatoes held at 48° F. for 24 days continued to ripen somewhat if held 4 additional days at 65° following storage. They failed to develop satisfactory color and quality, however, and decay increased rapidly. As a ripening and storage temperature, 48° proved unsatisfactory.

The next phase of the study concerned mature-green tomatoes ripened at 55° and 65° F. and stored at 32° and 38°. Slow ripening at 55° followed by storage at 32° and 38° favored extensive decay as shown by the results of two tests (tables 14 and 15).

Table 14.--Storage life of tomatoes ripened at 65° for 12 days or 55° F. for 28 days and then stored at 38° or 32° (test 1)

Fruit class and storage temperature	Storage period	Total fruits	Condition at end of storage		
			Edible	Softened[1]	Decayed
Fruits ripened at 65° F.:	*Days*	*Number*	*Percent*	*Percent*	*Percent*
38° F.	15	60	97	0	3
32° F.	15	60	100	0	0
38° F.	20	60	90	0	10
32° F.	20	65	100	0	0
38° F.	25	60	65	32	3
32° F.	25	56	98	0	2
38° F.	30	64	25	59	16
32° F.	30	58	75	21	4
Fruits ripened at 55° F.:					
38° F.	15	63	79	0	21
32° F.	15	47	85	0	15
38° F.	20	53	13	0	87
32° F.	20	65	82	0	18
38° F.	25	57	0	42	100
32° F.	25	63	35	13	52
38° F.	30	63	0	54	100
32° F.	30	62	24	16	60

[1] Softened fruits are generally of poor quality. Some soft fruits were also decayed.

Table 15.--Storage life of tomatoes ripened at 65° F. for 18 days or 55° for 29 days and then stored at 38° or 32° (test 2)

Fruit class and storage temperature	Storage period	Total fruits	Condition at end of storage		
			Edible	Softened[1]	Decayed
Fruits ripened at 65° F.:	*Days*	*Number*	*Percent*	*Percent*	*Percent*
38° F.	15	60	100	0	0
32° F.	15	60	100	0	0
38° F.	20	60	95	0	5
32° F.	20	65	100	0	0
38° F.	25	60	35	48	17
32° F.	25	56	76	18	6
38° F.	30	64	33	44	23
32° F.	30	58	96	4	0
Fruits ripened at 55° F.:					
38° F.	15	73	89	0	11
32° F.	15	79	91	0	9
38° F.	20	83	48	0	52
32° F.	20	79	89	0	11
38° F.	25	67	0	40	84
32° F.	25	81	64	11	25
38° F.	30	80	0	51	100
32° F.	30	71	35	14	51

[1] Softened fruits are generally of poor quality. Some soft fruits were also decayed.

Mature-green tomatoes ripened at 65° remained in satisfactory condition for 20 to 25 days at 32° and 15 to 20 days at 38°. Tomatoes ripened at either 55° or 65° kept better at 32° than at 38°.

Firm-ripe tomatoes stored at 32° and 38° for 15 days or more deteriorated rapidly when removed to 70°--often in 24 hours. It is imperative that they be consumed directly out of cold storage.

Ripe tomatoes held at 38° for 25 days or longer tended to become soft and many had a watersoaked appearance. The quality was very poor. Decay was also more serious at 38° than at 32°.

A test aboard ship showed that the most successful method for extending the storage life of tomatoes was to ripen mature-green fruits at a moderate rate at 58° F., and then store them at 32° to 35° (10). By this method ripe tomatoes were available for use in 12 to 20 days and remained in good condition for about 20 additional days.

SUGGESTED APPLICATION OF FINDINGS

The results obtained in these tests suggest the following ways of handling certain fresh vegetables for shipboard or overseas use. The suggestions apply only to the handling of high-quality produce. The handling methods listed below for cabbage, celery, and lettuce are suggestions for prolonging the storage life of these vegetables, and are not means of improving the original quality. These recommendations are based on the assumption that the vegetables would be used immediately after removal from refrigeration.

Cabbage:

Store at 32° to 38° F. Pack in polyethylene-lined crates for maintaining quality longer. Ventilate film liners with eight 1/4-inch holes.

Celery:

Store at 32° to 35° F. Pack in polyethylene-lined crates or in individual polyethylene or rubber hydrochloride bags. Use unperforated film liners with overlapping top edges, or individual bags with two 1/4-inch perforations. If quality of celery is not excellent, individual bags should be used rather than crate liners.

Lettuce:

Store at 32° to 35° F. Remove outside wrapper leaves before storing to reduce weight, volume, and subsequent decay. Pack in polyethylene-lined crates or in individual polyethylene, rubber hydrochloride, or polyester bags to reduce moisture loss and maintain quality. Use unperforated film liners with overlapping top edges, or individual bags with two 1/4-inch perforations. Individual bags will give better results than liners if decay is present.

Tomatoes:

Mature-green tomatoes should not be stored at low temperatures (32° - 45° F.). They fail to ripen, become injured, and develop extensive decay.

Tomatoes that are firm ripe at time of sailing should be stored at 32° to 35° F. If handled in this way they will be immediately available for up to 3 weeks.

If temperatures for moderate ripening are available, place mature-green tomatoes on shipboard at 57° to 59° F., until ripe; then store them at 32° to 35°. By this method tomatoes will be available for replenishment in 12 to 20 days after departure and should remain in good condition for 20 additional days if used directly out of storage.

LITERATURE CITED

(1) Bratley, C. O.
1945. Keeping Quality of Head Lettuce as Affected by Holding Temperature and Various Wrapping Materials. U. S. Dept. Agr., Handling, Transportation and Storage Off. Rpt. 161.

(2) Comin, Donald, and Junnila, William
1946. Water Loss from Vegetables in Storage. Ohio Agr. Expt. Sta. Bimo. Bul. 243, 31: 159-166.

(3) Hardenburg, Robert E.
1949. Moisture Losses of Vegetables Packaged in Transparent Films and Their Effect on Shelf-life. Amer. Soc. Hort. Sci. Proc. 53: 426-430.

(4) Hauck, Charles W.
1946. Shelf Life of Fresh Fruits and Vegetables Can be Lengthened. Ohio Agr. Expt. Sta. Bimo. Bul. 241, 31: 100-103.

(5) _____, and Crawford, John J.
1947. Salable Life of Seven Vegetables. Ohio Agr. Expt. Sta. Bimo. Bul. 264, 32: 96-101.

(6) McColloch, L. P.
1951. Alternarius Tenuis the Cause of a Tomato Fruit Rot. Plant Disease Reporter 35 (5): 234-236.

(7) _____, and Worthington, John T.
1952. Low Temperature as a Factor in the Susceptibility of Mature-green Tomatoes to Alternaria Rots. Phytopath. 42(8): 425-427.

(8) _____, and Worthington, John T.
1954. Ways to Prevent Chilling Mature-green Tomatoes. Pre-Pack-Age 7: 22-25.

(9) Morris, Leonard L., Pratt, Harlan K., and Tucker, Carl L.
1955. Lettuce Handling and Quality. Western Grower & Shipper 26(5): 14-18.

(10) Parsons, C. S.
1959. Extending the Storage Life of Cabbage, Celery, Lettuce, and Tomatoes Aboard a Navy Supply Ship. U. S. Dept. Agr., Mkt. Res. Rpt. 336.

(11) Phillips, W. R.
1957. Storage in Polyethylene Containers. Report of the Canadian Committee on Fruit and Vegetable Preservation for 1956. Summary contained in 1957 report of Canadian Dept. Agr., Ottawa.

(12) Platenius, Hans
1946. Films for Produce--Their Physical Characteristics and Requirements. Modern Packaging 20(2): 139-143, 170.

(13) _____, Jamison, F. S., and Thompson, H. C.
1934. Studies on Cold Storage of Vegetables. Cornell Univ. Agr. Expt. Sta. Bul. 602.

(14) Rygg, G. L., and McCoy, W. W.
1952. Lettuce Prepackaging Tested. Western Grower & Shipper 23(8): 44-46, 49-50, 52, 54.

(15) _____, and McCoy, W. W.
1952. Celery Packaging Success. Western Grower & Shipper 23(9): 42-45, 49.

(16) Schomer, H. A., Showalter, R. K., Hardenburg, R. E., and Thompson, B. D.
1955. Prepackaging Celery at Production Area in Florida. Fla. Agr. Expt. Sta. Horticulture Ser. 55-2.

(17) Stahl, A. L., and Vaughan, P. J.
1942. Pliofilm in the Preservation of Florida Fruits and Vegetables. Fla. Agr. Expt. Sta. Bul. 369.

(18) Stewart, J. K.
1955. Arizona Spring Lettuce Refrigeration Requirements During Marketing Periods. Amer. Soc. Hort. Sci. Proc. 65: 387-392.

(19) _____, and Burkhart, L.
1956. Effects of Temperature and Maturity on Lettuce in Transit. Western Grower & Shipper 27(4): 19.

(20) Thompson, H. C.
1917. Celery Storage Experiments. U. S. Dept. Agr. Bul. 579.

(21) Work, Paul
1935. Loss of Weight from Celery During Marketing as Influenced by Wrapping, Trimming, Temperature, and Humidity. Amer. Soc. Hort. Sci. Proc. 33: 569-578.

* U.S. GOVERNMENT PRINTING OFFICE : 1960 OF—551976